FACILITY FORM 602

N66-83332
(ACCESSION NUMBER)

11
(PAGES)

CR 74357
(NASA CR OR TMX OR AD NUMBER)

(THRU)

None
(CODE)

(CATEGORY)

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

RE-ORDER NO. 60-629

LUNAR PHYSICAL PARAMETER STUDY

PARTIAL REPORT No. 4

MEASUREMENT OF LUNAR PARAMETERS USING DOWNHOLE NUCLEAR LOGGING TOOLS

November 18, 1960

Contract NASw-6

1 of 11

RE-ORDER No. 60-629

LUNAR PHYSICAL PARAMETER STUDY

PARTIAL REPORT No. 4

MEASUREMENT OF LUNAR PARAMETERS
USING
DOWNHOLE NUCLEAR LOGGING TOOLS

OUTLINE

		Page
Introduction		1
I.	Point Source of Fast Neutrons	1
II.	Activation Using Natural Neutron Sources	5
III.	Gamma Radiation Source	6
Discussion		7
Conclusions		8

Introduction

For many years various forms of logs have been run on earth in oil wells in which a neutron source and some type of radiation detector have been used. For example, the neutron logs have been used to measure the hydrogen content of formations, particularly in formations where the hydrogen content is relatively low. In more recent years, various nuclear logs have been used to measure quantitatively the amount of certain elements present in the formation.

This report points out adaptations of the various techniques which may be used for logging holes in the moon. This report is restricted to the nuclear techniques which involve neutrons. The following are possibilities of investigating unknown materials using nuclear logging techniques. The assumption has been made that a consolidated hole is available.

I. Point Source of Fast Neutrons

Practical sources of fast neutrons are Pu-Be, Po-Be, Ac-Be, Ra-Be, etc., which involve the Be^9 $(\alpha,n)C^{12}$ reaction. All of these have been used for logging purposes on earth. The Pu-Be and Po-Be neutron sources are the most desirable because very little gamma radiation is emitted from these sources. Po-Be would be advisable in this case because of the 180-day half life.

If a hole were available which was approximately 3 feet or more in depth, it would be of interest to measure the epithermal (or resonance) neutron flux at two or more distances from the source. In effect, one would be measuring the Fermi age which is related to the slowing down properties of the medium. The epithermal flux has been measured in many instances on earth. For example, J. Tittman measured[1] the Fermi age in SiO_2 and $CaCO_3$ using indium foils. The Fermi age is determined by the slope of the linear relationship, on semi-log paper, of the flux versus r^2. There are a number of factors which affect the slowing down of neutrons[2] - the density, number of nuclei per molecule, the elastic cross section, the non-elastic cross section, the mass of the element, the scattering angle, original neutron energy, and the energy of the detected neutrons. From these, the most important are the density and mass of the element, i.e., the density and the amount of hydrogen present. Thus by knowing the epithermal neutron flux at two distances from a point source of fast neutrons, one may obtain a quantity which depends to a large

---

[1]Jay Tittman, J.A.P. 26, 394 (1954)

[2]Principles of Nuclear Reactor Engineering, S. Glasstone, Van Nostrand Pub. Co., pp. 91-95, 161-168.

extent on the density and the hydrogen content. If the density is known from other measurements, the hydrogen content may be determined. Such an interpretation would not be completely unambiguous, but the data would be of considerable interest. The density enters as the inverse square in the age equation and hence the age is rather sensitive to this parameter.

Figure 1 shows a plot of mean square distance ($\overline{r^2}$) for indium resonance neutrons versus percent water content. The points above 30% were taken from Tittle, et al[3]. The data for dry sand and limestone were taken from Tittman[1]. $\overline{r^2}$ for limestone was increased by the square of the ratio of the density of limestone to sandstone. The curve above 30% water content is quite independent of the type of matrix showing that the hydrogen concentration is the predominant factor in this range. Below 20%, it is known that the density also enters quite strongly. Thus if one knows the density, the hydrogen concentration of the lunar material could be measured rather accurately by measuring the indium resonance (or epithermal) neutron flux at two distances from the neutron source. Alternatively, if the hydrogen content is known, the density may be determined.

It would also be of interest to know whether or not any elements in the lunar material have a high thermal

---

[3] C.W. Tittle, et al, Tech. Rept. No. 21, Nuclear Shielding Studies, Lab. Nucl. Sc. & Eng. M.I.T. 8-31-49.

neutron capture cross section. This is quite easily done by measuring the thermal neutron flux and the epithermal neutron flux at some fixed distance from the neutron source. (see reference 2). For example, using a BF_3 counter, the measured thermal neutron flux is usually approximately 15 times greater than the epithermal neutron flux, measured using the same counter cadmium wrapped, in water. This ratio is 10 in a mixture of loose sand and water. However, with brine containing 250,000 p.p.m. NaCl in the sand-water mixture, the presence of chlorine makes this ratio decrease to 2.5. Thus it is rather simple to measure the presence or absence of the net effect of the sum of elements such as Cl, Cd, Sm, B, Li, Gd, etc.

The next step would be to use a Geiger counter at this same point. This would give an indication of the multiplicity of the gamma radiation. This would have to be calibrated on earth and would indicate the nature of the elements capturing neutrons. For example most elements in earth formations, except B, Cl, H, and Li, emit 1.9-2.1 γs/neutron captured. Cl emits 3.1 γs/neutron captured, while H and B emit 1 γ/capture, and Li none.

II. Activation Using Natural Neutron Sources

Some activation work can be done with natural point neutron sources. Usually it is somewhat difficult to interpret the data when two or more elements are activated which have comparable half lives. However, some times the results are unambiguous. It depends strictly on the amount and type of elements present.

On earth the most common elements which are activated when using Ra-Be, Po-Be, Pu-Be, or Ac-Be neutron sources are Al (half life τ = 2.3 min.), Si (τ = 2.3 min.), Na (τ = 15 hr.), and Cl (τ = 37 min.). Mn (τ = 2.6 hr.) in steel is quite often activated in cased wells.

The interpretation for the Na activation is usually unambiguous due to its long half life, although the time involved to make the measurement is considerable. Russian work has shown that 5-6 hours after activation is a sufficient time to accurately measure the sodium content of oil field waters. Na is activated by thermal neutron capture in Na^{23}.

Al and Si may be separated by using two different energy neutron sources. Al^{27} is activated by thermal neutron capture leading to Al^{28}. Si is activated through the $Si^{28}(n,p)\,Al^{28}$ reaction which has a Q = -3.87 MEV. The α-Be sources listed above will activate Si and Al, but a photo neutron source such as Na^{24}-Be will only activate Al. The neutrons from this source have a mean energy of 35 KEV.

By using a Pu-Be, Po-Be, or a Po-B neutron source, the material could be analyzed for flourine. The F^{19} (n, α) N^{16} has a practical threshold of approximately 3 MEV. N^{16} (τ = 7 sec.) emits maximum energy betas of 10.4 MEV, with 70% 6-7 MEV gamma radiation. Thus a beta counter would be convenient as a detector. The analysis for flourine would be unique if only high energy betas are detected. There are several elements having shorter half lives which may be activated, but interpretation would be quite difficult.

III. Gamma Radiation Source

Two elements for which analyses have been made[4] by using the γ,n reaction are Be and deuterium. The threshold of the reaction $Be^9(\gamma,n)\ Be^8$ is 1.66 MEV and of the reaction $H^2(\gamma,n)\ H^1$ is 2.22 MEV. One could monitor epithermal neutrons in the presence of Sb^{124} and a Na^{24} sources. Na^{24} (τ = 15 hr.) emits 1.37 and 2.75 MEV gamma radiation. Thus during the initial stages, both Be and D would undergo γ,n reactions if present. After the Na^{24} decays, only Be would produce neutrons due to the 60-day Sb^{124} which emits 1.71 and 2.11 MEV gamma radiation. In this method the density should be known for quantitative analyses.

[4]The determination of Be by the Photo Neutron Method, C.W.C. Miller and J.W. Edwards, A.E.R.E. - R 2965, Harwell, Berkshire (1959)

Discussion

The above ideas have been reduced to practice on earth, and presumably could be made in a physical form adaptable to logging on the moon. The hardware and manipulations have not been discussed. In general, activation studies would require more manipulations than the other measurements. The sources would generally weigh on the order of 8 oz. and the detectors 1-8 oz. It would be necessary to raise and lower both sources and detectors. Pertaining to the sources, it might be possible to have the alpha and Na^{24} sources separate from the Be and when a neutron source is needed, to insert one or the other into a cylindrical piece of Be. Thus, the Na^{24} source could be used as a photo neutron source and as a source for the γ,n studies. Also pertaining to sources, one could eject them by a spring-loaded device from the space crafts to get rid of them if necessary. The source strengths necessary would be in the .1-10 curie range. It may be necessary to caliper the borehole.

Conclusions

Using nuclear logging techniques, the following items could be measured in a consolidated borehole in the lunar surface:

1. The hydrogen content if the density is known, or the density if the hydrogen content is known.
2. The presence or absence of elements having high thermal neutron cross sections.
3. The multiplicity of the gamma radiation.
4. The amount of Be and D present.
5. By activation, the amount of Na, Al, Si, F, and Cl present.

FIGURE 1

Mean Square Distance ($\overline{r^2}$)

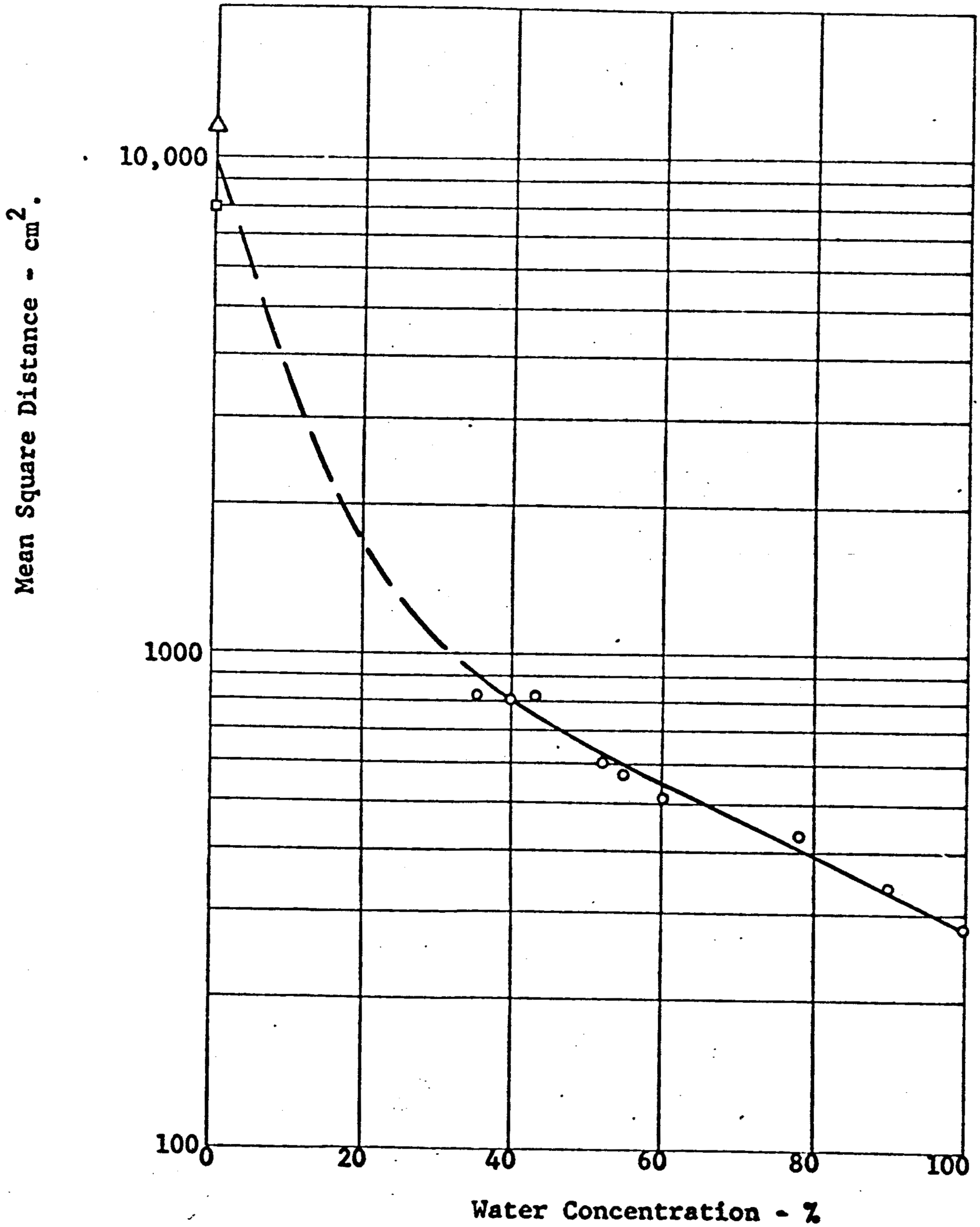
vs.

Water Concentration

△ = Sandstone[1]

□ = Limestone[1]

○ = Sandstone and other Matrices[3]



1:794.14-9
(1:794-14)